GRADUATE STUDY AND RESEARCH IN CIVIL AND SANITARY ENGINEERING

UNIVERSITY OF ILLINOIS **BULLETIN** JANUARY 1, 1954

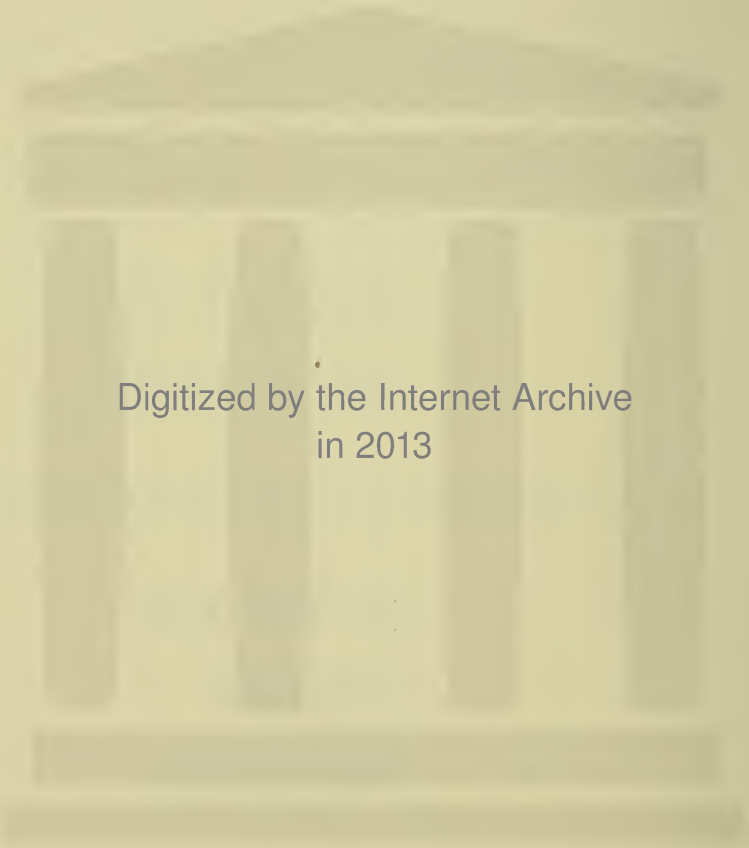
UNIVERSITY OF ILLINOIS BULLETIN

Volume 51, Number 40; January, 1954. Published seven times each month by the University of Illinois. Entered as second-class matter December 11, 1912, at the post office at Urbana, Illinois, under the Act of August 24, 1912. Office of Publication, 207 Administration Building, Urbana, Illinois.

GRADUATE STUDY AND RESEARCH

JANUARY 1, 1954

IN CIVIL AND SANITARY ENGINEERING



Contents

Graduate Faculty in Civil Engineering and Sanitary Engineering

WALTER JAMES AUSTIN, Ph.D.
Research Associate Professor of Civil Engineering

HAROLD EATON BABBITT, M.S.
Professor of Sanitary Engineering

EDWARD EZRA BAUER, M.S., C.E.
Associate Professor of Civil Engineering

JAMES GORDON CLARK, M.S.
Professor of Civil Engineering

ELLIS DANNER, M.S.
Professor of Highway Engineering

GEORGE HARPER DELL, Ph.D., C.E.
Professor of Civil Engineering

JESS C. DIETZ, Ph.D.
Professor of Sanitary Engineering

JAMES JOSEPH DOLAND, M.S., C.E., D.Sc.
Professor of Hydraulic Engineering

WILLIAM WALTER HAY, M.S., Mgt.E.
Associate Professor of Railway Civil Engineering

WHITNEY CLARK HUNTINGTON, M.S., C.E., D.Sc.
Professor of Civil Engineering and Head of Department

WILLIAM HERMAN MUNSE, M.S.
Research Associate Professor of Civil Engineering

NATHAN MORTIMORE NEWMARK, Ph.D.
Research Professor of Structural Engineering

WILLIAM ALBERT OLIVER, M.S., C.E.
Professor of Civil Engineering

RALPH BRAZELTON PECK, C.E., D.C.E.
Research Professor of Soil Mechanics

WILLIAM HORACE RAYNER, M.C., C.E.
Professor of Civil Engineering, *Emeritus*

MILTON OTTO SCHMIDT, Ph.D.
Professor of Civil Engineering

THOMAS CLARK SHEDD, M.S., C.E.
Professor of Structural Engineering

CHESTER PAUL SIESS, Ph.D.
Research Associate Professor of Civil Engineering

KARL TERZAGHI, Dr.Ing.
Lecturer and Consultant in Civil Engineering

THOMAS HAMPTON THORNBURN, Ph.D.
Research Associate Professor of Civil Engineering

JAMISON VAWTER, M.S., C.E.
Professor of Civil Engineering

CARROLL CARSON WILEY, B.S., C.E.
Professor of Highway Engineering, *Emeritus*

WILBUR M. WILSON, M.M.E., C.E., D.Eng.
Research Professor of Structural Engineering, *Emeritus*

General Comments

This pamphlet has been prepared especially for students considering graduate study in Civil Engineering and Sanitary Engineering. More complete information may be found in the catalog of the Graduate College which will be sent on requests addressed to that college. Any regulations and requirements included in the Graduate College catalog but not in this pamphlet apply to all graduate students including those in Civil Engineering and Sanitary Engineering.

The Department of Civil Engineering offers advanced study and professional training in the general fields of highway engineering, hydraulic engineering, railway engineering, sanitary engineering, soil mechanics and foundations, structural engineering, surveying, and traffic engineering. Facilities for research are available in all these fields and active research programs directed by members of the staff are under way. In programs of graduate study emphasis is placed on both course work and research.

The degrees of Master of Science and Doctor of Philosophy may be attained by qualified students who satisfy the requirements of the Department and the Graduate College. Progress toward an advanced degree is measured not only by the accumulation of units of credit in formal course work but also by evidence of intellectual growth and achievement.

The main purpose of graduate study is to enable a student to broaden his knowledge of and increase his competence in a given field. Graduate study, especially in the second and third years of the doctorate, aims at the development of independent scholarship, originality, and competence in research.

The graduate enrollment in Civil Engineering is about 125 students from all parts of the world. Because of this enrollment, it is possible to offer a wide range of courses on all phases of Civil and Sanitary Engineering. Also, the many foreign students bring to the department a variety of experience which broadens the outlook of all who are included in the graduate group.

The extensive research program involving an annual expenditure of several hundred thousand dollars creates an atmosphere of research and enables students to participate in and come in contact with active research projects. Research is supported by the University as a part of its educational program for undergraduate and graduate students. However, a large part of the research program is supported by special grants from various sponsors including federal and state agencies, technical societies, professional associations, and research councils. The present sponsors are as follows:

Illinois Division of Highways

Association of American Railroads

Engineering Foundation

United States Bureau of Public Roads

Research Council on Riveted and Bolted Structural Joints

Copper and Brass Research Association

Atomic Energy Commission

Engineering Research and Development Laboratories of Fort Belvoir, Virginia

Department of the Navy, Office of Naval Research, Bureau of Ships

Department of the Army, Office of Chief of Engineers, Ohio Division Laboratories

Department of Air Force, Directorate of Intelligence, Air Material Command

Many of the important developments in engineering are based on the research work which has been done in the laboratories of this department.

Because of the courses in structural engineering and soil mechanics and foundations which are regularly offered during the summer session, it is possible for members of the staffs of other universities to fulfill the requirements for the master's degree in four summers or to make progress toward the doctor's degree.

Importance of Graduate Study

The increasing complexity of many phases of engineering and recent scientific and industrial developments have created a strong demand for civil and sanitary engineers with training beyond that included in undergraduate programs of study. Fields of work for which graduate study is desirable and for which it prepares the engineer are as follows:

1. Advanced analysis, design, consulting, and administration in various specialized fields.
2. Teaching of both fundamental civil engineering courses and advanced work in civil engineering or related fields.
3. Research and development in industrial laboratories or at educational and scientific institutions and government organizations.

Formal graduate course work and participation in creative research enables the civil engineer with graduate training to go beyond the limitations of present practices and to contribute to the progress of his profession.

Admission

Applications for admission are processed by the Director of Admissions and Records. Application forms can be obtained from the Graduate College, the Director of Admissions, or the Civil Engineering Department. A qualified applicant can be admitted at any time, but, in order to avoid delays, a prospective student is urged to submit his application several weeks in advance of the opening of the session in which he plans to enroll.

An official transcript from each undergraduate college attended must be sent to the Director of Admissions and Records. Transcripts of students who enter the Graduate College can not be returned.

The general requirements governing admission are as follows:

Admission to the Graduate College with *full status* in Civil or Sanitary Engineering is granted to graduates of institutions whose requirements for the bachelor's degree are substantially equivalent to those of the University of Illinois, provided the applicant's grade-point average for the last fifty per cent of the hours completed for the bachelor's degree (exclusive of required physical education and military training) is at least 3.75 and his undergraduate preparation is appropriate to advanced study in his chosen major field. In converting to a numerical grade, the following equivalents are used: A = 5; B = 4; C = 3; D (the minimum passing grade) = 2.

Admission to the Graduate College with *advanced status* is granted upon recommendation of the department of the major field of study and the Dean of the Graduate College to applicants who hold a bachelor's degree, have completed one or more years of graduate study at an accredited institution, and who wish to become candidates for the Doctor of Philosophy degree at the University of Illinois. If advanced standing is granted, the amount of credit to be allowed will be determined by the Dean upon the recommendation of the major department.

Admission to graduate courses may be granted only to those who have had the requisite undergraduate work in those courses. Students whose preparation is considered inadequate may be required to take without credit certain undergraduate courses. But a student of mature age who satisfies the Dean of the Graduate College and the department concerned of his ability to pursue graduate work in a given line may be enrolled in particular graduate courses, without reference to a degree, and permitted to carry on such study or investigation under the direction of a department as the department shall recommend and the Dean approve.

Registration and Program of Studies

Registration. Dates for registration in the Graduate College are shown in the calendar, a copy of which will be sent upon request. Registration for the first semester is the middle of September; that for the second semester, the second week of February; and that for the summer session, the middle of June. A former graduate student who registers late must pay a late registration fee of $5. The registration of a new student will be accepted at any time, provided he is prepared to enter courses already under way for credit reduced in proportion to the length of time which has elapsed since instruction began. He is not charged the late registration fee.

A graduate student obtains a program card and other registration ma-

terial from the Graduate College office during scheduled registration days or at any time thereafter. The student should then consult his departmental adviser as explained below. The adviser will suggest the course of study and, in the case of a new student, will determine what deficiencies, if any, must be made up; these will be listed on a prerequisite blank. If there are no deficiencies, the adviser will so indicate on this form. When the program card has been approved by the adviser, the student will secure on it the signatures of the individual instructors in whose courses he is enrolled. The program of a student who has a staff appointment or who holds a University Fellowship must be approved by the Dean of the Graduate College before his registration is completed. This signature can be obtained on the first day of registration or at any time thereafter, but not before. Program cards of other students do not require the Dean's signature.

Advisers. Every graduate student must have an adviser, who will assist in planning and carrying through a program of graduate work which will fit the needs and wishes of the student. A new graduate student should go to the department office of his major field of study to discuss the selection of an adviser.

Unit Credit for Courses. Courses offering graduate credit are numbered from 300 to 399 when they are open to advanced undergraduates and to graduate students, and are numbered 400 and above when they are open to graduate students only.

Graduate credit is measured in terms of units. One unit is considered the equivalent of four semester hours. The normal program for a full-time graduate student is four units each semester; the maximum permissible is five. The credit which may be earned in individual courses is indicated in the course listing and is in some instances variable. The credit for which the student is actually registered in every specific course is entered on the student's program card by his adviser and is subject to the approval of the Dean of the Graduate College.

Miscellaneous Courses. A graduate student carrying a normal graduate program may elect one miscellaneous subject (a course which does not give credit toward an advanced degree). If it is necessary for a graduate student to carry at the same time more than one miscellaneous subject, he may not register for a full graduate program. Courses intended to give graduate students a reading knowledge of French or German are regarded as miscellaneous courses. A student who elects a miscellaneous course is required to register in it and do the assigned work.

Auditing Privileges. A graduate student is permitted to attend classes as an auditor, provided a card bearing the approval of his adviser and of the instructor is filed at the Graduate College office. A student should not enter on his program card courses which he will attend as an auditor.

Graduate Programs for Employed Students. A student who is employed can not expect to complete his academic work as promptly as he otherwise could. The academic work carried by assistants and others on the University staff is limited by statute. Those employed outside the University are expected to reduce their programs of work in accordance with these regulations. The maximum amount of academic work is determined by the terms of employment as follows:

	Maximum Registration	
Nature of Appointment	*Semester*	*Summer Session*
Full time	1 unit	1 unit
Three-fourths time	2 units	1 unit
Two-thirds time	2¼ units	1 unit
Half time	3 units	1½ units
One-third time	3½ units	2 units
One-fourth time	4 units	2 units

Time Limit for Advanced Degrees. For the time of entrance upon graduate study at the University of Illinois, the work for a master's degree must be completed in not more than six calendar years, and that for a doctor's degree in not more than seven calendar years.

Graduate Study in the Summer. During the summer session, a student may take courses for credit toward higher degrees, subject to the residence requirements listed below. The normal program for a summer term is two units; two and one-half units may be carried with the approval of the adviser. In no case will a student be permitted to carry more than two and one-half units.

A limited number of Civil Engineering graduate courses are offered during the summer session. The fields included are structures and soil mechanics and foundations. The courses offered vary from summer to summer, so that by careful planning, it is possible to complete the requirements for a master's degree by summer study and make progress toward the doctor's degree.

Students from Abroad. A foreign student who wishes to be admitted to graduate work at the University of Illinois should write to the Director of Admissions, enclosing copies of his academic records certified by the educational institutions previously attended. Immigration requirements demand that a foreign student admitted to this country as a non-quota student must register each semester for not less than three units of work if he is enrolled in the Graduate College.

The Dean for Foreign Students will assist foreign students with problems involving passports, visas, and other matters.

A foreign student whose native tongue is not English is required to take an examination in English before registration. If his command of the language is not adequate, he is required to enroll in courses for the study

of English as a foreign language. Credit earned in these courses will not apply to an advanced degree.

Grades. Grades are recorded by the following letters: A, B, C, D, E. Any student who receives two units of grade below B must complete two additional units of A or B grade to qualify for an advanced degree. Three units of a grade below B disqualify a student as a candidate. A grade of E in any course in the major field precludes the conferring of a degree in the academic year in which the failure is incurred.

Petitions. The normal procedures and requirements of the Graduate College are indicated in this pamphlet, but these may be modified occasionally for justifiable reasons. A student may petition the Dean and the Executive Faculty of the Graduate College for exceptions, but he should do so only after consultation with his adviser.

The Degree of Master of Science

The degree of Master of Science is offered in the fields of Civil Engineering and Sanitary Engineering.

Credit Requirements. A candidate for the master's degree must complete, with satisfactory grades, at least eight units including the thesis.

Residence Requirements. A candidate for the master's degree is required to be in residence for the equivalent of at least two semesters. A two-unit registration in a regular semester constitutes full residence. Students in actual residence who are carrying lighter programs of work must spend a proportionately longer time in satisfying this residence requirement; thus, for example, a full-time assistant registered for one unit each semester would discharge the residence requirement in four semesters of work.

Attendance during four summer sessions in each of which the student is registered for not less than one unit of work, or one semester with not less than two units and two summer sessions with not less than one unit each, is regarded as the equivalent of two semesters in residence.

Registration for more than two units in a regular semester, or for more than one unit in a summer session, will not shorten the time which must be spent to discharge the residence requirement.

Work Done Elsewhere. A graduate student who has done graduate work in other approved institutions may petition to obtain credit not to exceed four units toward the master's degree by passing examinations in that work. Admission to such examinations requires the prior approval of the Dean of the Graduate College. The acceptance of credit for work completed elsewhere does not reduce the residence requirement of two semesters.

If it is recommended in advance by the adviser, the Graduate College may permit a student to register for work at a laboratory elsewhere offering

facilities not available at Urbana, or in approved field work, with the understanding that such work will be accepted for graduate credit if completed satisfactorily. The adviser will examine the student's transcript and will examine the student directly when he returns to this campus and will then make a final recommendation to the Dean of the Graduate College concerning the credit to be given.

Majors and Minors. A candidate for a master's degree may do all his work in one field, or he may select a major and one minor, or a major and two minors, as indicated in specific cases in the latter part of this pamphlet. A major or minor denotes the field of knowledge of a department, or such part thereof as constitutes a separate and independent division of that field. For a master's degree a major comprises work totaling a minimum of four units. Less than one unit of work will not satisfy the requirements for a minor.

Thesis. The subject of a thesis for the master's degree must be filed at the Graduate College office *by the student during the registration period prior to his graduation.* A student usually devotes two units of work to his thesis, and no more than three units of thesis credit may be earned except by special permission. For specific instructions with reference to the preparation and form of the thesis, the student should obtain at the Graduate College office a copy of the leaflet "Instructions for Preparation of Theses." Two copies of the thesis with a Certificate of Approval must be presented to the Graduate College office. The Certificate of Approval for the master's thesis must be signed by the person under whose immediate supervision the thesis was prepared and also by the head of the major department. Blank certificate forms can be obtained at the Graduate College office.

The requirement of a thesis may be waived, on the recommendation of the adviser and with the approval of the Dean, *provided application to waive the thesis is made at the time for announcing thesis subjects.* A student excused from writing a thesis must replace it with courses of instruction. In general, a student excused from writing a thesis will be required to earn a total of nine units of credit. Only in special cases will the thesis requirement be waived for research assistants.

Thesis Work on Leave of Absence. A student who has completed six units of course work in residence and wishes to complete his thesis in absentia should submit a petition to the Executive Faculty. The petition must include an outline of the proposed investigation, evidence that adequate facilities for pursuing it will be available, and a statement of approval by the student's adviser.

Suggested Programs. Suggested programs in the various fields in Civil and Sanitary Engineering are presented on page 30.

Conferring of Degrees. The master's degree is conferred in February,

June, August, and October. Each student is responsible for entering on his registration cards, during the registration period preceding the time at which he expects to be awarded his degree, the fact that he is a candidate for a degree to be awarded at the end of that semester. If the candidate is not currently registered in the Graduate College, he must present his application to receive a degree at the Graduate College office no later than the final date specified by that college.

Not later than one week before the degree is conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College. The student must obtain all the signatures called for on the form and return it to the Graduate College.

The Degree of Doctor of Philosophy

The degree of Doctor of Philosophy is offered in the fields of Civil Engineering and Sanitary Engineering.

Residence Requirements. For the degree of Doctor of Philosophy, the student must spend three "years" in resident study at an accredited educational institution; such "years" are defined as follows:

First "Year." The time required to complete eight units of graduate work with satisfactory grades and to pass one foreign language examination.

Second "Year." The time required to progress from the completion of the first year's work through the completion of the preliminary examination. This involves obtaining satisfactory grades in eight more units of graduate work, passing the second foreign language examination, and passing the preliminary examination.

Third "Year." The time spent between passing the preliminary examination and the completion of all requirements for the doctor's degree, including eight units of research, writing a satisfactory thesis, and passing the final examination.

A student who spends the first two years in residence at the University of Illinois may petition to spend the last year in absentia. A student who has completed the first year of graduate work elsewhere must be in residence during the two remaining years. In exceptional cases, a student with two years of graduate study elsewhere who satisfies his major department that he has completed work equivalent to the standard departmental requirements will be permitted to take his preliminary examination, provided he has fulfilled the language requirements. If such a student passes the preliminary examination, he may complete the requirements for the Doctor of Philosophy degree by devoting the third year to research in residence.

A student may satisfy the residence requirement in part by attending summer sessions at the University of Illinois. Attendance during four summer sessions is considered the equivalent of one year's residence. However, at

some time during the second or third years of his doctoral program, the student must be in residence at the University through two successive semesters.

Majors and Minors. A candidate for the degree of Doctor of Philosophy is required to pursue a major subject in the area of his research interest. He also is required to choose one or two minor subjects. If only one minor is chosen, it is called a "sole minor," and must be taken in an area other than that of the major. Credit for it must be earned by work representing not less than four units. If two minors are chosen, the first may be a subject closely related to the major. With the approval of the adviser, it may be a division of the major field of study; it must involve at least two units. In such a case, the second minor (not less than two units) must be taken in an area other than that of the major.

Language Requirements. The student will be required to demonstrate his ability to read two of the following languages: French, German, or Russian. He should take his language examinations as early as possible. The Department may designate the semester in which the student must pass the first examination. The student must pass his second language examination at least two months before his preliminary examination, or during the semester (or summer session) preceding that in which he is admitted to the preliminary examination. Certification of proficiency in foreign languages will not be accepted from other colleges or universities. The examinations must be taken at the University of Illinois.

Doctoral Committee. A permanent doctoral committee for each student will be appointed by the Dean of the Graduate College upon recommendation of the executive officer of the department in which the student is doing his major work. The committee will conduct the preliminary and the final examinations.

Preliminary Examinations. A candidate for the doctor's degree must pass a preliminary examination intended to test his knowledge of his major and minor fields of study. He will not be admitted to the examination before (1) he has passed the two required language examinations or their equivalent, (2) he has satisfactorily completed at least sixteen units of graduate work, and (3) his adviser and the head of the department of his minor field of study consider that he has adequate preparation in his major and minor fields. This examination, conducted by the candidate's doctoral committee, will be partly or entirely oral.

Final Examinations. When the thesis has been completed, if the major adviser so recommends, the candidate will be given his final examination by his doctoral committee. A student in the third year of study who fails to meet the expectations of the professors in charge of his work, or in any way

fails to maintain the standard of scholarship and power of research expected of him, may be refused admission to the final examination.

The final examination must be completed at least two weeks before the degree is conferred. This examination is concerned primarily with the research work of the student as embodied in his thesis, but it may be much broader and extend over the whole field of study of the candidate. The intention of the final examination is to determine that the candidate has a satisfactory grasp of his major subject as a whole, and a general acquaintance with the fields of knowledge represented by his course of study.

The final examination is oral and will be conducted entirely in the presence of the doctoral committee.

Thesis. The Doctor of Philosophy is primarily a research degree; consequently, the candidate is required to demonstrate his capacity for independent research by the production of an original thesis on some topic connected with his major field of study. The subject of the thesis should be chosen by the end of the second year and must be reported to the doctoral committee and the Graduate College at the time of the preliminary examination. The student should be registered in his thesis course for the number of units corresponding to the amount of time devoted to thesis research, four units being the equivalent of full-time work.

Not later than two weeks before the time set for his final examination, and not later than four weeks before the time when he hopes to receive the degree, the candidate must submit to the Graduate College, for approval of the format, two typewritten copies of his thesis in final form, *the original on* 20 to 24 pound bond and the first carbon on 16 to 20 pound bond paper. The style and form of the thesis must comply with the regulations given in the leaflet "Instructions for Preparation of Theses," copies of which can be obtained in the Graduate College office. After the thesis has been checked at the Graduate College office, the student must arrange that each member of the doctoral committee has an opportunity to read the thesis before the date of the final examination. At the conclusion of the candidate's final examination, the thesis must be deposited at the Graduate College office.

Formal publication of the thesis, either in its entirety or in a condensed form, is not required. However, students should consider the advantages to them, and to their professional field, of publication of the significant methods and findings of their research in the technical literature. If published, the article or book should have a note indicating that the material is, or is based upon, a dissertation submitted in partial fulfillment of the requirements for the Ph.D. (or other) degree at the University of Illinois.

In order to insure that theses will be available for the use of others, it is required that they be microfilmed. Each candidate who passes the final

examination must pay a fee of $30.00 and deposit an abstract of his thesis of approximately six hundred words, together with the required copies.

Conferring of Degrees. The doctor's degree is conferred in February, June, and October. Not later than one week before the degree is to be conferred, each candidate for an advanced degree must obtain a clearance paper from the Graduate College office. The student must obtain all the signatures called for on the form, and then return it to the Graduate College.

Fellowships and Assistantships

University Fellowships. University Fellowships are awarded each year to promising graduate students for work in any field in which the University offers a master's or doctor's degree. Fellowships carry exemption from tuition and all fees of the regular academic year, except the Hospital and Medical Service Fee of $5 a semester, during the period of the fellowship. The stipends are as follows: first-year fellowship, $900; second-year fellowship, $1,000; third-year fellowship, $1,100.

The holder of a University Fellowship is granted free tuition for the summer session following the termination of the academic year in which his fellowship was effective, if he desires to continue his studies during the summer. A candidate for a fellowship must be a graduate of the University of Illinois, or of a college or university having equivalent requirements for the bachelor's degree. An applicant for a first-year fellowship must have his bachelor's degree from an accredited educational institution, a high scholastic average, and adequate preparation for graduate work in his major field. To be eligible for a second-year fellowship an applicant must have completed one year of graduate study and must have passed one language examination. An applicant for a third-year fellowship must pass the preliminary examination no later than one month after the beginning of the semester during which the fellowship is effective.

Application must be made on blanks obtained from the Dean of the Graduate College and should be submitted before February 15 of the academic year preceding that for which the fellowship is desired. An application received later than February 15 will not be considered until after April 15.

A person appointed is notified on April 1, and must send the Secretary of the Board of Trustees notice of his acceptance or refusal by April 15. If he accepts, he must agree that the appointment will not be resigned to take a similar one at any other institution during the year for which it is awarded, that he will not engage in any outside employment for remuneration, and that, without the consent of the University, he will neither attempt

to hold concurrently any other fellowship carrying a stipend, nor abandon the appointment during the year.

Resident Post-Doctoral Fellowships. A limited number of post-doctoral fellowships carrying a maximum stipend of $3,000 a year are provided. These fellowships are intended to provide opportunities for further training and development for outstanding students of great originality who wish to make additional use of the research facilities of the University after receiving the doctor's degree. The recipient must enter upon the fellowship within one year of the time when he received the doctorate. An applicant must submit a detailed program of research or study which he has conceived and formulated himself, and he will be interviewed by the Graduate College Fellowship Committee. Applicants should apply for this fellowship by February 15, although it may be possible to consider applications at other times during the year.

Research Assistantships in the Engineering Experiment Station. The Engineering Experiment Station is devoted to the study of problems of special importance to engineering and to the stimulation and elevation of engineering education. By undertaking a line of graduate study in close association with some one of the projects carried on in the Station, the student will come into contact with aspects of his specialty which he would rarely touch in a purely academic study, and will thus broaden his outlook. The Experiment Station makes available apparatus, equipment, and the services of machinists, which materially facilitate the carrying on of investigations.

Research assistantships, with a stipend of $1,350 for a college year of two semesters, are open to graduates of approved technical colleges and universities. These assistantships carry exemption from tuition and all fees of the regular academic year, except the Hospital and Medical Service Fee of $5 a semester. Applicants to whom these assistantships are awarded agree to hold them for two college years, devoting one-half of their time to the work of the Engineering Experiment Station. At the end of this period, if all requirements have been met, the degree of Master of Science will be conferred. Each appointment is made for one college year and is renewed for the second year if an assistant's services are satisfactory.

Appointments to research assistantships are made only to men with outstanding records or other excellent qualifications. Appointments are given to first- and to second-year graduate students, but only rarely to third-year students who have not previously studied at Illinois. In general, with a half-time assistantship, two academic years of residence are required in order to obtain the master's degree.

A number of research assistantships in civil and sanitary engineering are available. They include assistantships established by the University,

and others provided by cooperative research agreements with state and federal agencies, technical societies, and engineering associations. Fields of research which are now active include steel, concrete, and wood structures, structural welding, soil mechanics, foundations, retaining walls, culverts, earth dams, highway pavements, hydraulic engineering, and sanitary engineering. It is usually possible to assign a research assistant to a project in the field of his special interest. Often the research in which he is engaged will form the basis of his thesis, but his thesis is not restricted to this field.

Applications for research assistantships should be made to the Director of the Engineering Experiment Station not later than March 15 to be considered with the initial group. However, applications received after that date will be considered if vacancies still exist.

Fees and Expenses

Persons holding fellowships or research assistantships are exempted from payment of the tuition, laboratory, library, and supply fees. All other students registering for resident work pay fees each semester as listed below. There are reduced fees for the summer session.

Tuition Fee	*Regular Schedule (Over two units)*	*Reduced Schedule (Two units or less)*
Residents of Illinois	$ 50.00	$16.00 per unit
Nonresidents of Illinois	160.00	44.00 per unit
Laboratory, Library, and Supply Fee	11.00	5.50
Hospital and Medical Service Fee. Students who present evidence of participation in any other insurance system providing the same benefits as those covered by the University fee may petition the Dean of Students for refund of this fee. Students registered for one unit or less are exempt from this fee.	5.00	5.00
Illini Union Service Charge. Students registered for one unit or less are exempt from this fee.	7.00	7.00
Late Registration Fee. Former students, whether on appointment or not, who register after the regular registration days in either semester are subject to this fee.	5.00	5.00

Buildings and Equipment

The teaching and research activities of the Department of Civil Engineering are conducted in large portions of two major buildings — Civil Engineering Hall and Talbot Laboratory — and completely occupy three

smaller buildings — the Sanitary Engineering Laboratory, the Surveying Building, and the Hydraulic Engineering Laboratory. A summer surveying camp with a capacity of over one hundred is located at Camp Rabideau in the lake region of northwestern Minnesota.

Civil Engineering Hall. This building has a floor area of 64,000 square feet. It contains design rooms to provide tables for junior and senior civil and sanitary engineering students, and a similar room restricted to the use of graduate students.

An outstanding Engineering Library is conveniently located in this building. The stack capacity of over 70,000 volumes is completely occupied by books on engineering and related subjects in English, German, French, and other languages and contains all significant engineering periodicals and journals in the various languages. In addition, over 55,000 of the less used engineering books are kept in the Main Library. The departmental libraries in Physics, Mathematics, Chemistry and Chemical Engineering are housed in nearby buildings. The Engineering Library has a seating capacity of over two hundred.

The Department offices and student lounge are located in this building.

Talbot Laboratory. The Talbot Laboratory is the outstanding building of its kind in the country. Its floor area of 82,000 square feet is shared by the Department of Civil Engineering and the Department of Theoretical and Applied Mechanics. It houses the following laboratories for testing, research, and instruction. The *structural laboratory* is in the large central crane bay, where testing machines varying in capacity from 30,000 pounds to 3,000,000 pounds are located. The latter machine has a vertical height sufficient to accommodate tension and compression specimens 38 feet long. Large machines for determining the fatigue strength of full-size structural members are important features of this laboratory. The laboratory is served by a traveling crane. Extensive facilities are available for studying the behavior of structures and structural components of wood, steel and other metals, reinforced concrete, and prestressed concrete and for the study of vibrations in structures and their action under impact loads, earthquake motions, or blast forces.

The *concrete laboratory* is equipped for the study of proportioning and mixing concrete and of its physical properties. The *highway materials laboratories* are equipped for tests and research in bituminous and nonbituminous highway materials. The *soils laboratories* are equipped to perform the various soil tests and provide excellent facilities for research. The *wood laboratory* is equipped for the various tests of wood specimens and for testing joint connected wood structures.

Also available for civil engineering research are a number of *computing machines* of various types for use in numerical methods of stress analysis and for the study of vibrations, buckling, and other problems. Electric desk

calculators are located in computing laboratories in Talbot Laboratory and in Civil Engineering Hall. Use may be made of the IBM punched card tabulating and computing equipment in the Statistical Service Bureau. Use may also be made, under supervision, of the high-speed electronic digital computer which the University has built. This computer is one of the best of its type in the country, with a memory capacity of 1,024 numbers of 40 binary digits (13 decimal digits) and a multiplication speed of approximately 1,200 pairs of numbers per second. Codes are available by which solutions may be obtained for sets of linear simultaneous equations, containing up to 39 variables, in less than two minutes and for other complicated or tedious problems. This computer makes possible the investigations involving complex computations which would be impracticable or even impossible by other means and greatly expands the scope of analytical research.

A radar speed meter, several automatic traffic recorders, and other traffic study equipment are available for highway traffic research.

Graduate students in civil engineering commonly elect courses which make use of the laboratories of the Department of Theoretical and Applied Mechanics which are also located in this building. The laboratories include the *hydraulics laboratory,* which is equipped with a standpipe, pumps, weirs, orifice tanks, turbines, long concrete channels, and other facilities for instruction and research in hydraulics; the *applied mechanics laboratory,* equipped with standard and special testing machines of various types and capacities; the *fatigue of metals laboratory,* equipped with a variety of machines for testing metals under fatigue loading; the *concrete research laboratory,* which is well equipped with testing machines, mixers, a concrete saw, a core drill, and other tools and equipment used in fabricating and testing members of plain and reinforced concrete and which is supplemented by the large crane bay and its testing machines; and several special laboratories, such as those for railroad rails, plastics, photoelastic investigations, and creep of metals.

Two well-equipped machine shops are provided for use in making and repairing equipment and apparatus for instruction and research.

Sanitary Engineering Laboratory. This building is modern in every respect and well equipped. It has a floor area of 5,000 square feet and provides classrooms, offices, and laboratories for instruction and research in sanitary engineering. Sewage is supplied to apparatus in this building by a connection with the main city outfall sewer adjacent to the building. Research in the purification of water, in the treatment of sewage and of industrial wastes, and in other branches of sanitary engineering requiring hydraulic, chemical, and biological equipment is being carried on in the Sanitary Engineering Laboratory. Opportunities to participate in the established projects and to pursue research independently on selected projects are offered.

Surveying Building. This building is located near the surveying fields on the south campus. Its floor area of 9,400 square feet is divided among drafting rooms, classrooms, offices, and an instrument room which is well equipped with transits, levels, plane tables, and other instruments for plane and topographic surveying, precise levels and theodolites for geodetic surveying, and special instruments for aerial mapping.

Hydraulic Engineering Laboratory. The Hydraulic Engineering Laboratory occupies a space of approximately 10,000 square feet. It is provided with a pumping capacity of 2,500 gallons per minute at heads from 40 to 45 feet. Storage and sump facilities furnish 22,000 gallons. The piping arrangements are designed to permit operation of simultaneous experiments without interference.

Instrumentation is of the latest types. A unique feature of the laboratory is a heated space 10 feet wide and 330 feet long equipped with a traveling crane for the handling of heavy equipment. This space is well adapted to studies relating to either open channel or pipe flow.

Available within the laboratory are complete shop facilities for the construction of models, including apparatus for moulding plastic materials.

Cameras for both still and moving pictures are a part of the regular equipment. A darkroom permits the processing of photographs. Mechanical calculators are available for the analytical interpretation of experimental data.

Courses in Civil Engineering and Sanitary Engineering

The prerequisite for graduate work in civil engineering and sanitary engineering is the equivalent of the undergraduate courses required for the degree of Bachelor of Science in the branch of the subject in which registration is desired.

Courses or Graduates

401. **Geodetic Engineering.** Elements of geodesy; principles and practice of precise triangulation, traverse, and levels. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering. SCHMIDT.

402. **Geodetic Engineering.** Astronomic determination of latitude, longitude, and azimuth; systems of plane coordinates; map projections; electronic and special control surveys. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering. SCHMIDT.

420. **Highway Pavement Design I.** Analysis and methods of measurement of road surface properties related to vehicle performance; factors affecting pavement durability; traffic wear, climate, chemical action, combined effects; composition design of flexible and rigid pavements for proper road surface properties, load carrying capacity, wear resistance, stability and durability. I; 1 unit. Prerequisite: Civil Engineering 220, or equivalent. E. DANNER.

421. **Highway Pavement Design II.** Structural design of flexible and rigid pavements; loading characteristics, static, impact and repeated loads; load distribution through pavement layers, factors affecting distribution, methods of analysis; evaluation of subgrade support; criteria for selecting design values. II; 1 unit. Prerequisite: Civil Engineering 420, or consent of instructor. E. DANNER.

422. **Municipal Administration and Engineering.** Legal authority of municipalities, forms of municipal government; municipal functions, organization, and management; city finance; engineering functions of city government; city planning and zoning, building codes and inspection; street lighting; public utilities; city cleaning; recreational development. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. E. DANNER.

423. **Traffic Planning.** Traffic planning functions; urban and rural master traffic plans; traffic analyses for new streets, highways, and terminal facilities. II; 1 unit. Prerequisite: Civil Engineering 323, or equivalent. E. DANNER, LEEK.

424. **Airport Design.** Selection of site, soil investigation, layout, drainage, runway design and construction, hangars and other structures, and other civil engineering features of airport design and construction. I, II; 1 unit. Prerequisite: Graduate standing in civil engineering.

425. **Railroad Location and Operation.** Track and traffic capacity, optimum size of train, train performance diagram, train scheduling and make-up, improvement of existing lines, examples of modern location. I; 1 unit. Prerequisite: Civil Engineering 203, 226, or equivalent experience, or consent of instructor. HAY.

426. **Railroad Location and Operation.** Roadbeds under load, roadbed stabilization, design of ballast section, ties, rails, and fastenings, economies of grade separation, recent examples of roadway and track problems. II; 1 unit. Prerequisite: Civil Engineering 425, or equivalent, or consent of instructor. HAY.

440. **Water Supply.** Design, pumping machinery, administration, and operation. I; 1 unit. Prerequisite: Bachelor of Science degree in sanitary engineering, or equivalent. BABBITT.

443. **Sewerage.** Sewer design, construction, maintenance, operation, and financing. II; 1 unit. Prerequisite: Bachelor of Science degree in sanitary engineering, or equivalent. BABBITT.

444. **Sewage Disposal, Wastes Disposal, and General Sanitation.** Principles and design of sewage treatment and waste disposal works. II; 1 unit. Prerequisite: Bachelor of Science degree in sanitary engineering, or equivalent. BABBITT.

446. **Water Purification and General Sanitation.** Design of water purification works and principles of sanitation. I; 1 unit. Prerequisite: Bachelor of Science degree in sanitary engineering, or equivalent. BABBITT.

448. **Sanitary Engineering Laboratory.** Tests of water supply; sewerage; water purification and sewage treatment equipment and processes. I, II; 1 to 2 units. BABBITT.

450. **Hydrology and Flood Control.** Magnitude and frequency of flood flow of streams, minimum flow of streams, and regulation of flow by storage reservoirs; intense rainfall and the development of intensity curves for use in rational run-off formula; unit-graph method of computing flood run-off;

flood control and prevention by channel improvement, levees, and reservoirs. I, II; 1 unit. Prerequisite: Civil Engineering 250, or equivalent. DOLAND.

452. **Water Resources Planning and Development.** Purposes and techniques of planning water resources developments; methods of evaluating the engineering and economic aspects of water conservation projects developed through the examination of actual proposals. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. DOLAND.

455. **Water Power Engineering.** Preliminary investigations of site, available water supply, machinery selection, design of water passages, arrangement and space allocation in power houses, load curve studies, hydrosteam association, and speed and pressure regulation. I, II; 1 unit. Prerequisite: Civil Engineering 250 or 450. DOLAND.

457. **Hydraulic Engineering Laboratory.** Design, construction, and testing of individual or semi-individual laboratory studies. Study and discussion of advanced subjects of hydraulic engineering phenomena. I; 1 to 2 units. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. DOLAND.

458. **Open Channel Flow.** Classification of types of flow, channel roughness, backwater curve computations, hydraulic jump analysis, special transitions, canal design, study of supercritical velocity flow, unsteady flow and flood movements. Modern developments in open channel flow theory and design practice. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. DOLAND.

460. **Structural Analysis.** Basic theory of indeterminate structures; deflections and displacements; continuous beams and frames; virtual work; qualitative and quantitative influence lines. I, II; 1 unit. Prerequisite: Bachelor of Science degree in engineering and undergraduate course in theory of simple structures. VAWTER, OLIVER.

461. **Structural Theory and Design.** General theory of continuity; moment distribution; the column analogy; rigid frame bridges and buildings; fixed and continuous arches; classification of structures from viewpoint of design. I, II; 1 to 2 units. Prerequisite: Bachelor of Science degree in civil engineering with a basic course in indeterminate structures. SHEDD, VAWTER.

462. **Structural Theory and Design.** Statically indeterminate trusses; continuous trusses; steel arches; secondary stresses; suspension bridges; long-span roofs; skeleton steel buildings. I, II; 1 to 2 units. Prerequisite: Bachelor of Science degree in civil engineering with a fundamental course in indeterminate structures. SHEDD, VAWTER.

464. **Reinforced Concrete Design.** Theories of action of beams, slabs, and columns of reinforced concrete; codes and specifications and their influence on design; effect of continuity. I, II; 1 unit. Prerequisite: Bachelor of Science degree in engineering with undergraduate courses in structures. SHEDD.

465. **Steel Design.** Design of steel members; codes and specifications for buildings; riveted and welded connections; evolution of bridge specifications; loads and working stresses; economic proportions. I, II; 1 unit. Prerequisite: Bachelor of Science degree in engineering with undergraduate courses in structures. SHEDD.

466. **Investigations in Reinforced Concrete Members.** The actual behavior and ultimate strength of reinforced concrete structural elements are studied by means of critical reviews of the more significant experimental and analytical

investigations. Emphasis is placed on the empirical nature of current specifications and codes and their relation to the results of research. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering with undergraduate or graduate courses in structures and reinforced concrete design. SIESS.

467. **Investigations in Reinforced Concrete Structures.** Behavior of reinforced concrete structures. Critical reviews of experimental and analytical investigations. Statically indeterminate reinforced concrete structures: frames, floor slabs, column footings, highway bridge floors. II; 1 unit. Prerequisite: Civil Engineering 466, or consent of instructor. SIESS.

469. **Wood Structures.** Theory and practice in the design of modern wood structures; the effect of the plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design and the development of design formulas. I, II; 1 unit. OLIVER.

470. **Earth Pressures and Retaining Walls.** A study of earth pressures considering the significant properties of soils; methods of computing earth pressures and the limitations in their dependability; stability computations; and the design and construction of retaining walls and abutments. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering. HUNTINGTON.

471. **Earth and Masonry Dams.** Stability of rolled-fill and hydraulic-fill earth dams and rock-filled dams; methods of construction; seepage losses; control of seepage forces; safety of foundation. Solid gravity, arched gravity, arch, multiple arch, and slab and buttress dams; safety against sliding and overturning; unit stresses on horizontal sections and principal stresses; joints; drainage; foundations. II; 1 unit. HUNTINGTON, PECK.

473. **Soil Mechanics.** Advanced studies of research techniques in soil mechanics and foundation engineering. I; 1 unit. Prerequisite: Civil Engineering 374, or consent of instructor. PECK.

474. **Foundation Engineering.** Critical study of case histories of projects in foundation engineering; current procedure for design and construction of foundations, embankments, and waterfront structures. II; 1 unit. Prerequisite: Credit in Civil Engineering 373, or consent of instructor. PECK.

481. **Numerical and Approximate Methods of Structural Analysis.** Methods of successive approximations and numerical procedures for the solution of complex problems, with applications to bridges, buildings, and aircraft structures: influence lines, moments and deflections of beams with axial load, buckling strength of columns and frameworks, moments and deflections of beams resting on elastic or plastic supports, vibrations of beams and of complex structural assemblies. I; 1 to 2 units. NEWMARK, AUSTIN.

482. **Numerical and Approximate Methods of Structural Analysis.** Numerical methods applied to simple elements and complex structures subjected to dynamic loads, including earthquake and bomb blast. Methods of successive relaxation of constraints, energy methods, difference equations, method of collocation, and method of least squares, with applications to the following problems: torsion of solid sections, torsion of thin-walled sections, shear center, bending of plates and of stiffened plates, plane stress problems in elasticity, and other special topics. I or II; 1 to 2 units. NEWMARK, AUSTIN.

483. **Analysis and Design of Plates and Slabs.** Fundamental theory of bending and buckling of plates, including stiffened plates; practical application of theories in analysis and design of reinforced concrete bridge and building floors, high-

way and airport pavements, and structural plate components in metal. I; 1 to 2 units. Prerequisite: Consent of instructor. NEWMARK.

484. **Behavior of Structures Under Dynamic Loads.** Analysis of the effects of wind load, earth tremors, impact, and explosion blast on buildings and bridges; vibrations of and impacts on structural components, with particular emphasis on beams, slabs, and columns; propagation of stress waves in steel and concrete; effects of damping and inelastic action; self-excited vibrations with application to cables and suspension bridges. II; 1 unit. Prerequisite: Civil Engineering 461, or equivalent. NEWMARK.

485. **Analytical Study of Tests of Structural Steel Members.** A critical review and study of the fundamental behavior of steel structures and their components with particular attention to connections, members, and frames of riveted, welded, and bolted construction. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering with undergraduate courses in structures and strength of materials. MUNSE.

486. **Design of Lightweight Structures.** Analysis and design of structures and structural members of minimum weight. I, II; 1 to 2 units. Prerequisite: Bachelor of Science degree with previous work in statically indeterminate structures. CLARK.

487. **Earthquake and Bomb-Resistant Structures.** Nature of dynamic loading; nature of dynamic resistance of structures; methods of analysis; significance and interpretation of results of analysis; criteria for design of resistant structures; application to actual problems. II; 1 to 2 units. NEWMARK.

491. **Thesis (Master's).** I, II; 1 to 2 units.

492. **Thesis (Doctor's).** I, II; 1 to 2 units.

493. **Special Problems.** Individual investigations or studies of any phase of civil engineering selected by the student and approved by his adviser and the staff member who will supervise the work. (See Suggested Topics for Civil Engineering 493 below.) I, II; ½ to 2 units.

495. **Highway Seminar.** Presentation and discussion of current problems and research developments in highway transportation, administration, and engineering. (Should be followed by Civil Engineering 496.) I; no credit. E. DANNER.

496. **Highway Seminar.** A continuation of Civil Engineering 495. Presentation and discussion of current problems and research developments in highway transportation, administration, and engineering. II; no credit. E. DANNER.

Suggested Topics for Civil Engineering 493

A sufficient number of regular courses have been established to cover adequately some phases of civil engineering. Even in these, students may wish to take advantage of Civil Engineering 493 for special studies. In other phases, extensive use is made of Civil Engineering 493 to cover subjects not now included in the regular courses. The following topics are suggested, but registration is not restricted to these topics.

HIGHWAY AND TRAFFIC ENGINEERING

Highway Transportation. Transportation in general, functions and types; development of highway transportation; elements of highway transport and their functions; economic aspects; regulation of transportation. I; 1 unit.

Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. E. DANNER.

Highway Organization and Administration. Elements of the U. S. highway system; division of responsibilities; forms of administrative organization; legislative control; highway finance; planning and programming; personnel management; accounting records and statistics; public relations; research programs; contracts; policing; legal affairs. II; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. E. DANNER.

Highway Laws and Regulations. Street, highway, and traffic department legal rights and responsibilities; eminent domain proceedings; freeway laws; traffic laws and ordinances; driver licensing; vehicle inspection. I; 1 unit. Prerequisite: Bachelor of Science degree in civil engineering, or consent of instructor. E. DANNER, LEEK.

Geometric Highway Design. Highway classification; highway capacity; width and types of highways; sidewalks, curbs, medians, channelization; intersection types and design; sight distance; horizontal and vertical layout; design standards. II; 1 unit. Prerequisite: Civil Engineering 323, or equivalent. E. DANNER, LEEK.

Traffic Operations. Theory of traffic control; theory of sign, signal and marking design and operation; one-way streets; turn controls; parking; street lighting; miscellaneous traffic control designs. II; 1 unit. Prerequisite: Civil Engineering 323, or equivalent. E. DANNER, LEEK.

Traffic Accidents and Safety. Analysis of traffic accidents, vehicular and pedestrian; types and causes; engineering factors in accidents; regulations and policing; driver and public education; organization of safety programs; coordination of engineering, education, and enforcement. II; 1 unit. Prerequisite: Civil Engineering 323, or equivalent, or consent of instructor. E. DANNER, LEEK.

Highway Subgrade Soils

Highway Economics and Finance

Highway Materials

Roadway Design

Highway Planning and Programming

Highway Maintenance and Operation

History and Development of Highways

Analysis of Traffic Problems

HYDRAULIC ENGINEERING

Hydraulics of Surface Drainage I. Applications of hydraulics and hydrology. Elements of channel design, economical sections, energy analyses, non-uniform flow; design flow determination by precipitation analysis, stream flow records, flood analysis; bridge opening hydraulics, stream continuity, backwater; hydraulics of culverts, energy concepts on super and subcritical slopes, culvert components. I; 1 unit. Prerequisite: Theoretical and Applied Mechanics 232. DOLAND, GUILLOU.

Hydraulics of Surface Drainage II. Detailed hydraulic analysis of overland flow, flow in gutters and paved ditches, storm water inlets; design of sewers, routing interceptors, design, analysis, and location of culverts; design and analysis of bridge openings; stream improvements, channel relocations;

erosion control on fills, cuts, gully protection, and stream erosion. II; 1 unit. Prerequisite: Hydraulics of Surface Drainage I. DOLAND, GUILLOU.

Irrigation

Navigation

Sanitary Aspects of River Control

RAILWAY ENGINEERING

Yards and Terminals

Signaling

Grade Crossing Elimination

Economics of Train Operation

Rail Design and Defects

Track Under Load

Courses for Graduates and Advanced Undergraduates

306. **Photogrammetry.** A study of aerial surveying in civil engineering practice. Characteristics and interpretation of aerial photographs; stereovision; mosaics; economics of photogrammetry; map reproduction. Practice in the preparation of a topographic map from aerial photographs. I; ½ unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp); senior standing, or consent of instructor. C. S. DANNER.

319. **Advanced Surveying.** Advanced problems in topographic engineering; control surveys, special mapping projects, construction surveys, and special surveys. The utilization of maps and survey data in civil engineering practice. II; ½ unit. Prerequisite: Civil Engineering 207 (Summer Surveying Camp); senior standing, or consent of instructor. SCHMIDT.

323. **Highway Traffic Characteristics.** Driver characteristics, vehicle characteristics, and traffic behavior as related to highway design and operation; traffic studies, field problems. I; 1 unit. Prerequisite: Civil Engineering 220, or consent of instructor. LEEK.

332. **Engineering Properties of Soils.** Laboratory practice in testing, identification, and classification of soils; study of development of test procedures and basic theories involved; calculations and preparation of graphs using test data. Tests include those for (1) classification, (2) determination of physical properties, and (3) job control. I, II; ½ unit. Prerequisite: Senior standing in engineering, or consent of instructor. BAUER.

344. **Water and Sewage Treatment.** Principles, design, and operation of water purification and sewage treatment works. I; 1 unit. Prerequisite: Credit or registration in Bacteriology 104 and Civil Engineering 240 or 241. BABBITT, DIETZ.

345. **Public Health Engineering.** Principles of sanitation, waste collections, and disposal; sanitary regulations, biostatistics. II; ½ unit. Prerequisite: Credit or registration in Bacteriology 104 and Chemistry 122. BABBITT.

351. **Drainage and Flood Control.** Land drainage, river improvement, flood control. II; ½ unit. Prerequisite: Civil Engineering 250. DOLAND.

355. **Water Power Engineering.** Analysis of hydrologic and power market data; selection of site and hydraulic machinery; preliminary design of water pas-

sages and power house; formal reports on projects. II; 1 unit. Prerequisite: Civil Engineering 250. Doland.

356. Hydraulic Engineering Laboratory. Fundamental principles, operation and use of model laboratories, dimensional analysis, hydraulic similitude, theory and design of hydraulic models. II; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234. Guillou.

359. River Hydraulics. Gaging of streams, stream erosion and deposition, use of groins, revetments and mats, stream systems, and river navigation. I; ¾ unit. Prerequisite: Theoretical and Applied Mechanics 232. Doland.

361. Statically Indeterminate Structures. Elastic theory and its applications to statically indeterminate structures. I, II; ½ unit. Prerequisite: Civil Engineering 262; credit or registration in Civil Engineering 264.

362. Statically Indeterminate Structures. I, II; ½ unit. Prerequisite: Civil Engineering 361, or 262 and consent of instructor.

370. Foundations and Retaining Walls. Evaluation of subsoil conditions; choice of type and basis for design of foundations; earth pressures and retaining wall design. I, II; 1 unit. Prerequisite: Civil Engineering 230 and 263, or consent of instructor.

371. Earth and Masonry Structures. Analysis and design of masonry dams; earth dams and embankments, and substructure for bridges and buildings. I, II; ½ unit. Prerequisite: Credit or registration in Civil Engineering 264 and 370.

373. Introduction to Soil Mechanics. Identification, description, and physical properties of soils; subsurface exploration; engineering characteristics of natural deposits of soil. I; 1 unit. Prerequisite: Credit or registration in Civil Engineering 370, or consent of instructor. Peck.

374. Applied Soil Mechanics. Application of soil mechanics to foundations of buildings; damage due to construction operations. II; 1 unit. Prerequisite: Civil Engineering 373. Peck.

375. Engineering Aspects of Surficial Soils. Use of geologic, pedologic, and air-photo information for identification and evaluation of the engineering properties of surficial soils. II; 1 unit. Prerequisite: Civil Engineering 230, or consent of instructor. Thornburn.

Courses in Theoretical and Applied Mechanics

Courses for Graduates

412. Vibration Analysis. A continuation of Theoretical and Applied Mechanics 311. Specific topics are systems of several degrees of freedom; application of generalized coordinates; Lagrange's equations and coordinate coupling; vibration of elastic bodies, including strings, rods, and beams; analysis by means of the Laplace transformation. Some special problem assignments are torsional vibrations, including natural modes, forced vibration, and dampers; vibrations of airplane structures and propellers; balancing of rotating and reciprocating machines; balancing machines. II; 2 units. Prerequisite: Theoretical and Applied Mechanics 311.

416. Energy Methods in Mechanics of Materials. The derivation, interpretation, and application of various principles of energy and of related potential functions for determining the relations between loads on members and the resulting deflections and internal forces. Specific topics are the principles of strain

energy and so-called complementary energy; Castigliano's theorem; principles of least work, minimum potential energy, and virtual work; a comparison of the principles and methods with emphasis on advantages and limitations of the methods under various conditions, including linear elasticity and nonlinear behavior; applications of the methods of engineering problems involving both statically determinate and statically indeterminate members. I; 1 unit. LANGHAAR.

421. Mechanics of Materials. Methods of obtaining relations between loads and stresses and strains in various members. The main topics covered in this course and the one which follows are curved beams, unsymmetrical bending, thick-walled cylinders, beams on elastic supports, contact stresses, torsion of members with non-circular cross-section, stress concentrations, elastic energy methods applied to statically indeterminate members, flat plates, inelastic behavior of various types of members. Introduction to mathematical theory of elasticity; elastic and plastic buckling; criteria of failure by yielding and by fracture. I; ½ to 1 unit. SMITH.

422. Mechanics of Materials. Continuation of Theoretical and Applied Mechanics 421. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 421. SMITH.

424. Properties of Engineering Materials. Significance of properties under various conditions of loading and use, including static, creep and fatigue, and impact properties; tests and interpretation of test data; methods of obtaining special combinations of properties; effects of temperature, strain rate, internal structure, etc.; specifications of properties and materials. II; ½ to 1 unit. COLLINS.

431. Applied Fluid Mechanics. A course designed to illustrate applications of dimensional analysis, the energy principle, and the momentum principle in practical analyses of flow problems. Dimensional analysis is developed systematically. It is employed to develop model laws, the von Kármán theory of unidirectional turbulent flow, the correlation between the Chezy formula and the Darcy formula, and other topics. The energy principle is applied to problems of transient flow, the theory of gravity waves, and flow in open channels. The momentum principle is applied to the theory of open-channel flow, the theory of the hydraulic jump and the plane shock, and the theory of the boundary layer. I; 1 unit. Prerequisite: Theoretical and Applied Mechanics 232; one advanced mathematics course is desirable. LANGHAAR.

432. Theory of Flow of Incompressible Fluids. A course emphasizing topics in classical fluid mechanics which are the basis of many modern developments. The material consists of fundamentals of frictionless flow, Euler's differential equations of motion, velocity potentials, stream functions, sources and sinks, complex potential functions, conformal mapping. Blasius' theorems of lift and moments, vortex motion line vortices and vortex sheets, stresses in viscous fluids, Navier-Stokes equations, and differential equations of the boundary layer. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 232; one advanced mathematics course is desirable. LANGHAAR.

436. Dimensional Analysis and Theory of Models. A course developing the basic methods of dimensional analysis, with applications to the theory of models and the planning of experiments. An integrated picture of important applications in various fields of engineering and a broad understanding of the uses and limitations of the subject are presented. Specific topics are selected from the following: nature and use of dimensions; principles of dimensional analysis; systematic calculation of dimensionless products; algebraic theory of di-

mensional analysis; similarity and model laws; differential equations and similarity; dimensional analysis applied to problems of stress and strain, fluid mechanics, theory of heat, and electrical engineering. II; ½ to 1 unit. LANGHAAR.

451. **Theory of Elasticity with Application to Engineering Problems.** A study of the mechanics of elastic deformable bodies, based on the fundamental concepts of equilibrium, geometry of strain, and properties of materials. Relations between stresses, strains, and displacements are studied in detail with special consideration given to their significance in engineering problems. I; 1 unit. LANGHAAR.

452. **Theory of Elasticity with Application to Engineering Problems.** Continuation of Theoretical and Applied Mechanics 451. II; 1 unit. Prerequisite: Theoretical and Applied Mechanics 451. LANGHAAR.

461. **Inelastic Behavior of Engineering Materials.** An outline of a general theory of inelastic behavior. A study of the mechanisms of inelastic action involving viscosity, plasticity, and fracture in relation to yielding or flow, creep, fracture under repeated loads and under impact. Relation of inelastic behavior to planning of tests, to the interpretation of test results, and to design. I; ½ to 1 unit. Prerequisite: One year of graduate work. SMITH.

462. **Inelastic Behavior of Engineering Materials.** Continuation of Theoretical and Applied Mechanics 461. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 461. SMITH.

464. **Theory of Buckling.** Analysis of elastic stability of columns, frames, rings, arches, beams, plates, cylindrical shells, and curved sheet panels; extensions of the theory to inelastic buckling; behavior after buckling. II; 1 unit. LANGHAAR.

491. **Thesis (Master's).** I, II; 1 to 2½ units.

492. **Thesis (Doctor's).** I, II; 1 to 2½ units.

493. **Special Problems.** Individual investigation of studies, either analytical or experimental, in one or more phases of theoretical and applied mechanics, including mechanics of materials, theory of elasticity, properties of materials, mechanical vibrations, hydraulics and fluid mechanics, etc. I, II; ½ to 2 units.

Courses for Graduates and Advanced Undergraduates

311. **Mechanical Vibrations.** Kinematics of vibratory motion; comprehensive study of motion having single degree of freedom; critical speeds of shafts; vibration of systems with several degrees of freedom. Applications to engineering problems. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 154 or 156, or 211 and 221. JONES.

321. **Advanced Mechanics of Materials.** Methods used in elementary mechanics of materials are expanded and generalized and used to solve more complex problems. Thick-walled cylinders, torsion of bar having non-circular cross-section; curved beams, unsymmetrical bending, flat plates; theories of failure. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223. BLACK, SMITH.

323. **Advanced Laboratory in Materials Testings.** Calibration of testing machines and of strain measuring instruments; use of various mechanical and electrical strain gages; interpretation of test results; relation of tests to specifications of materials. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223. COLLINS, PUTNAM.

326. **Experimental Stress Analysis.** Methods of extending and applying basic physical laws to the measurement of stresses or deformations that are of significance in the engineering design of load resisting members. Systematic applications of optical, electrical, and physical properties of matter to the instrumentation and measurement of model or prototype stresses. Among the topics studied are photoelasticity, significant mechanical characteristics of materials, accuracy vs. sensitivity of measurement, dynamometers, and strain measuring devices, measurement of vibration stresses, models and analogies, brittle coatings, electrical resistance gages, etc. I, II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 221 and 223; 321 desirable. DOLAN.

334. **Fluid Mechanics and Advanced Hydraulics.** A study of the basic properties of fluids in general, particularly those that influence the flow of fluids in pipes and open channels, viscosimetry, dimensional analysis, effect of boundary conditions, cavitation, water tunnel, hydraulic jump, water hammer, pumps, turbines. Some laboratory work. II; ½ to 1 unit. Prerequisite: Theoretical and Applied Mechanics 232 and 234. LANSFORD.

Suggested Programs for the Master's Degree

The following programs are presented as an aid to the student in evaluating the possibilities of advanced study in the various fields of civil engineering and in sanitary engineering. Changes in these programs may be made by the student in consultation with his adviser in order to adjust the graduate study to the student's background and to his particular field of interest.

Research assistants, who follow half-time programs of graduate study, will cover the same material as would be required of full-time students, but will usually take two to three units of work each semester for their two years of study instead of the four or five units of work each semester as suggested below.

HIGHWAY ENGINEERING

First Semester		Units
C.E. 373	Introduction to Soil Mechanics	1
C.E. 420	Highway Pavement Design I	1
C.E. 493	Special Problems	
	Highway Transportation	1
	Hydraulics of Surface Drainage I	1
C.E. 495	Highway Seminar	0
		4

Second Semester		Units
C.E. 375	Engineering Aspects of Surficial Soils	1
C.E. 421	Highway Pavement Design II	1
C.E. 493	Special Problems	
	Geometric Highway Design	1
	Highway Organization and Administration	1
	Hydraulics of Surface Drainage II	1
C.E. 496	Highway Seminar	0
		5

Other Courses. A student may wish to emphasize some special phase of Highway Engineering such as drainage, soils, surfaces, materials, traffic, or administration. For this reason, he may wish to substitute other courses in the program which more nearly fit his needs. A full program in Traffic Engineering is outlined under that heading.

HYDRAULIC ENGINEERING

First Semester	Units
C.E. 373 Introduction to Soil Mechanics	1
C.E. 450 Hydrology and Flood Control	1
C.E. 457 Hydraulic Engineering Laboratory	1½
C.E. 470 Earth Pressures and Retaining Walls	1
	4½

Second Semester	Units
C.E. 351 Drainage and Flood Control	½
C.E. 452 Water Resources Planning and Development	1
C.E. 455 Water Power Engineering	1
C.E. 458 Open Channel Flow	1
C.E. 471 Earth and Masonry Dams	1
	4½

Other Courses. Special problems in Hydraulic Engineering or courses in other fields related to it may be substituted for some of the subjects suggested above. Special attention is called to the desirability of Theoretical and Applied Mechanics 431, 432, and 433.

RAILWAY ENGINEERING

First Semester	Units
C.E. 373 Introduction to Soil Mechanics	1
C.E. 425 Railroad Location and Operation	1
C.E. 493 Special Problems or other selected course	1
Econ. 384 Economics of Transportation	1
	4

Second Semester	Units
C.E. 374 Applied Soil Mechanics	½
C.E. 426 Railroad Location and Operation	1
C.E. 471 Earth and Masonry Dams	½
C.E. 493 Special Problems	2
Selected Course	1
	5

Other Courses. In addition to the courses in Special Problems there are a number of graduate courses in the Civil Engineering Department and in other departments of the University which may be included as part of this program.

SANITARY ENGINEERING

First Semester	Units
*Bact. 300 General Microbiology	1
*Chem. 485 Chemistry of Water Treatment	1
C.E. 440 Water Supply	1
C.E. 446 Water Purification and General Sanitation	1
C.E. 491 Thesis	½
	4½

Second Semester	Units
C.E. 345 Public Health Engineering	½
C.E. 443 Sewerage	1
C.E. 444 Sewage Disposal, Wastes Disposal, and General Sanitation	1
*C.E. 448 Sanitary Engineering Laboratory	1
C.E. 491 Thesis	1
	4½

Other Courses. Any of the following courses, whose descriptions are included in the Graduate College catalog, may be suitable for those marked * above:

Bacteriology 300, 308, 326
Chemistry 326, 336, 337, 350, 397, 398, 485
Civil Engineering — any 300 or 400 series course
Mathematics 341, 342, 345, 369, 370
Physical Education 403
Political Science 305, 306, 312, 406
Veterinary Pathology and Hygiene 332
Zoology 343

SOIL MECHANICS

SOIL MECHANICS AND FOUNDATIONS

First Semester	Units
C.E. 332 Engineering Properties of Soils	½
C.E. 373 Introduction to Soil Mechanics	1
C.E. 460 Structural Analysis, or C.E. 461 Structural Theory and Design	1
C.E. 470 Earth Pressures and Retaining Walls	1
Geol. 450 Geology for Civil Engineers	1
	4½

Second Semester	Units
C.E. 374 Applied Soil Mechanics	1
C.E. 375 Engineering Aspects of Surficial Soils	1
C.E. 471 Earth and Masonry Dams	1
C.E. 474 Foundation Engineering	1
C.E. 493 Special Problems	½
	4½

STRUCTURES AND FOUNDATIONS

First Semester	Units
C.E. 373 Introduction to Soil Mechanics	1
C.E. 461 Structural Theory and Design	1
C.E. 470 Earth Pressures and Retaining Walls	1
Geol. 450 Geology for Civil Engineers	1
	4

Second Semester	Units
C.E. 374 Applied Soil Mechanics	1
C.E. 462 Structural Theory and Design	1
C.E. 465 Steel Design	1
C.E. 471 Earth and Masonry Dams	1
C.E. 474 Foundation Engineering	1
	5

Other Courses. Special Problems in Soil Mechanics and Structures or other courses in these and related fields may be substituted in the above programs according to the student's previous work and the objectives of his study.

STRUCTURAL ENGINEERING

Because of the wide range of subjects covered in this field, three alternative programs are suggested, each with emphasis on a different aspect of the general field. Each of these programs involves several suggested courses supplemented by others which may be selected from the entire list of offerings in the Department of Civil Engineering or in other departments. In general, substitution of courses leading to somewhat different specializations may be arranged in conference with the adviser.

Students who are taking half-time programs of graduate study as research assistants are permitted and encouraged to take three courses each semester for four semesters. They will ordinarily take the suggested courses listed but will have more time available for elective subjects. However, a research assistant is required to include two units of thesis in his program.

STRUCTURAL ANALYSIS AND DESIGN

First Semester	Units
C.E. 373 Introduction to Soil Mechanics	1
C.E. 461 Structural Theory and Design	1
C.E. 464 Reinforced Concrete Design	1
Selected Courses	1½
	4½

Second Semester	Units
C.E. 374 Applied Soil Mechanics	1
C.E. 462 Structural Theory and Design	1
C.E. 465 Steel Design	1
Selected Courses	1½
	4½

Other Courses. Graduate students with normal backgrounds, who are interested primarily in structural design, will ordinarily find it advantageous to choose other courses from the following:

Civil Engineering 370, 371, 466, 467, 469, 470, 471, 481, 482, 483, 484, 485, 486, and 493

Theoretical and Applied Mechanics 321, 323, 326, 421, 422, 424, 451, 452, 461, 462

The selections should be made in consultation with the adviser in order to ensure a program that best fits the student's particular needs.

STRUCTURAL THEORY AND RESEARCH

First Semester	Units
C.E. 461 Structural Theory and Design	1
C.E. 481 Numerical and Approximate Methods of Structural Analysis	1
Math. 345 Differential Equations and Orthogonal Functions	1
T.A.M. 421 Mechanics of Materials, or T.A.M. 451 Theory of Elasticity with Application to Engineering Problems	1
	4

Second Semester	Units
C.E. 462 Structural Theory and Design	1
C.E. 464 Reinforced Concrete Design	1
C.E. 482 Buckling, Vibrations, and Impact	1
T.A.M. 422 Mechanics of Materials, or	
T.A.M. 452 Theory of Elasticity wth Application to Engineering Problems	1
Selected Course	1
	5

STRUCTURAL DYNAMICS

First Semester	Units
C.E. 461 Structural Theory and Design	1
C.E. 481 Numerical and Approximate Methods of Structural Analysis	1
Math. 345 Differential Equations and Orthogonal Functions	1
T.A.M. 421 Mechanics of Materials, or	
T.A.M. 451 Theory of Elasticity with Application to Engineering Problems	1
	4

Second Semester	Units
C.E. 482 Buckling, Vibrations, and Impact	1
C.E. 484 Behavior of Structures under Dynamic Loads	1
C.E. 487 Earthquake and Bomb-Resistant Structures	1
T.A.M. 422 Mechanics of Materials, or	
T.A.M. 452 Theory of Elasticity wth Application to Engineering Problems	1
Selected Course	1
	5

Other Courses. A wide variety of courses both in the Department of Civil Engineering and other departments are available for electives in the two programs above.

TRAFFIC ENGINEERING

First Semester	Units
C.E. 323 Highway Traffic Characteristics	1
C.E. 493 Special Problems	
Highway Laws and Regulations	1
Highway Transportation	1
C.E. 495 Highway Seminar	0
Math. 369 The Ideas and Methods of Statistics	1
	4

Second Semester	Units
C.E. 423 Traffic Planning	1
C.E. 493 Special Problems	
Geometric Highway Design	1
Highway Organization and Administration	1
Traffic Accidents and Safety	1
Traffic Operations	1
C.E. 496 Highway Seminar	0
	5

Other Courses. Work in special problems listed under Civil Engineering 493, Highway and Traffic Engineering, and City Planning 372 may be substituted for certain of the courses suggested above.

ENGINEER OFFICERS' PROGRAM

Summer Session	Units
C.E. 460 Structural Analysis	1
C.E. 464 Reinforced Concrete Design	1
	2

Four Weeks Following Summer Session	Hours
C.E. 160 Building Construction and Materials	3
C.E. 290 Contracts and Specifications	2
	5

Fall Semester	Units
C.E. 373 Introduction to Soil Mechanics	1
C.E. 420 Highway Construction	1
C.E. 450 Hydrology and Flood Control	1
C.E. 470 Earth Pressures and Retaining Walls	1
Geol. 450 Engineering Geology	1
	5

Spring Semester	Credit
C.E. 248 Water Supply and Sewerage (not required of civil engineering graduates who have had similar training)	4 hours
C.E. 374 Applied Soil Mechanics	1 unit
C.E. 455 Water Power Engineering	1 unit
C.E. 465 Steel Design	1 unit
C.E. 471 Earth and Masonry Dams	1 unit
	4 units
	4 hours